Danish Offshore Technology Centre
Technology Conference 2024

Structural integrity of the diatom- and smectite-rich mudstone from the Nora Formation, Sten-1 well, Danish North Sea

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Hydrocarbon migration from chalk reservoirs to fine-grained overburden sediments raises concerns about wellbore stability in decommissioning wells. Understanding the petrophysical properties of these formations is essential. By interpreting seismic, well-logging, and petrographic data, we identified diatom-rich mudstone intervals in the Nora Formation of the Sten-1 well. This well represents several wells nearing decommissioning.

We characterized solid composition from 10 cuttings in the diatom- and smectite-rich mudstone using X-ray diffraction and interpolation. Porosity was derived by correcting the neutron log for hydrogen attenuation due to lithology (Fig. 1). The compositional analysis enabled us to derive the solid phase elastic bulk and shear moduli, and we calculated the saturated-state P-wave modulus which was converted to dry-state using the Iso-frame model.

Our results indicated a Biot coefficient (α) log ranging from 0.96 to 0.99, suggesting grain-to-grain electrostatic contact without cementation. Vertical elastic strain (ε) calculations showed elevated strain (0.2%) between 1510 and 1600 m msl, indicating potential for structural damage and fracturing. Given the matrix is highly impermeable, we are investigating if fractures could facilitate fluid flow.

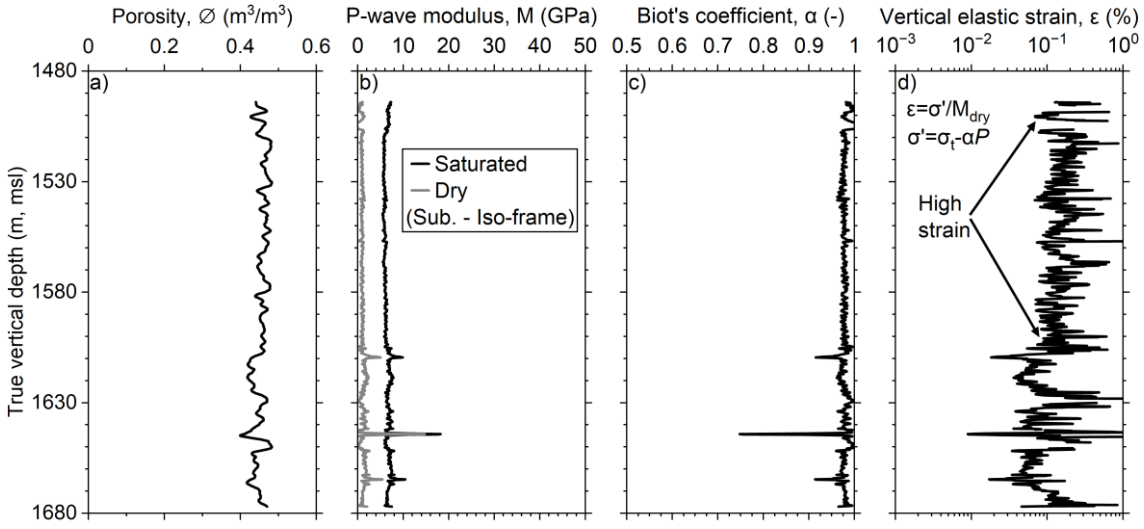

Fig. 1: Petrophysical properties of the water-saturated Sten-1 well, including a) porosity, b) saturated- and dry-state P-wave modulus, with bulk and shear moduli derived from compositional analysis and linear combination of mineral moduli, c) Biot's coefficient, and d) vertical elastic strain calculated from vertical elastic stress (σ') and dry-state P-wave modulus. Overburden stress (σ_t) was calculated using 1.98 g/cm³ bulk density, and pore pressure (P) assumed equal to mud pressure.